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Two new species of deep-sea Red Corals (Coralliidae, Genus *Hemicorallium* Gray, 1867) from the western Indian Ocean

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Abstract

Deep-sea corals are critical to global exploration of deep-sea biodiversity, but research on them in the Indian Ocean is very limited. In this study, we report the first discovery of two new species of red corals at a depth of 1697 m in the western Indian Ocean. The species were identified through detailed morphological analysis, including microscopic examination of colony structure, branches and autozooids (assessing size, abundance and spacing), as well as scanning electron microscopy (SEM) of sclerite morphology and quantity. Two species for the genus *Hemicorallium* Gray, 1867 were found as new species, designated *Hemicorallium indicodensum* **sp. nov.** and *Hemicorallium jiaolongensis* **sp. nov.** *H. indicodensum* **sp. nov.** is characterised by densely branched structures and numerous globular double-club sclerites, distinguishing it from other species. Meanwhile, *H. jiaolongensis* **sp. nov.** features yellowish-white colonies with short rods with sharp, large radial projections in the tentacles. Four mitochondrial regions were used to reveal the phylogenetic relationship in Coralliidae, supporting the taxonomic placement of these two new species. This study provides significant new insights into the biodiversity of deep-sea corals in the Indian Ocean, enriching the known species pool. Additionally, a more comprehensive key to the genus *Hemicorallium* is provided, further enhancing our understanding of the group's taxonomy.

Key Words

Deep-sea corals, *Hemicorallium*, Indian Ocean, molecular phylogenetics, morphological description, new species

Introduction

Deep-sea corals, particularly octocorals, play a crucial role in marine ecosystems by providing habitat, protection and food resources (Genin et al. 1986; Roberts 2009; Pham et al. 2015; Ramirez-Llodra 2020). The family Coralliidae, an important group within deep-sea octocorals, is notable for its precious red corals, distinguished by their unique red calcareous skeletons (Nonaka and Muzik 2007). These distinctive biological and ecological features confer significant economic value (Tsounis et al. 2010; De Carvalho 2018).

The establishment of the Coralliidae family dates back to 1812 (Lamouroux 1812). Since then, octocorals possessing a continuous calcareous axis and covered by a thin coenenchyme have been classified as members of this family. Before the 21st century, morphological methods were the only approach for classifying and identifying red corals (Lamouroux 1812; Ridley and VPZS 1882; Bayer 1956). With the development of molecular biology, the combination of phylogenetic analysis and morphological classification allowed the Coralliidae family to be divided into three genera for a long time (Ardila et al. 2012; Uda et al. 2013; Figueroa and Baco 2014): *Corallium* Cuvier, 1798, *Hemicorallium* Gray, 1867 and *Pleurocorallium* Gray, 1867. However, following the phylogenomic reconstruction of the Octocorallia in McFadden et al. (2022), significant taxonomic changes led to the merger of these three genera with genera from the Paragorgiidae

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(unaccepted now) and some from the Alcyoniidae Lamouroux, 1812, expanding the Coralliidae to 14 genera. The description of a new genus in 2023 further increased the total to 15 genera (Altuna and López-González 2023). The genus *Hemicorallium* has undergone multiple resurrections and reorganisations, yet further clarification remains necessary (Ardila et al. 2012; Uda et al. 2013; Tu et al. 2016; Morgan et al. 2023). Most taxonomic studies of *Hemicorallium* species originate from the Pacific waters around Hawaii (Tu et al. 2016; Nonaka and Hayashibara 2021) and the Sea of Japan (Nonaka et al. 2023), with a notable lack of species descriptions in the Indian Ocean. Currently, only six records in the Indian Ocean from other genus in Coralliidae (Sautya et al. 2011) are listed on NOAA's Deep Sea Coral Research and Technology Program website (https://deepseacoraldata.noaa.gov/).

The Indian Ocean covers vast tropical and temperate areas, featuring diverse seabed topographies and ecosystems (Smith and Sandwell 1997; De and Gupta 2010; Wafar et al. 2011), including deep-sea plains, trenches, seamounts and mid-ocean ridges (Smith and Sandwell 1997), making it a hotspot for deep-sea ecosystem diversity (Ramirez-Llodra et al. 2010; Zhou et al. 2022). The Carlsberg Ridge is a seismically-active mid-ocean ridge system in the north-eastern part of the Indian Ocean (Stein and Cochran 1985; Raju et al. 2008). This site of dynamic tectonic activity, where a new oceanic crust is continuously forming (Iyer and Ray 2003), provides varied habitats for many benthic communities (Sautya et al. 2017). Research on deep-sea corals in the depths of the Carlsberg Ridge is severely lacking, which limits our comprehensive understanding of the region's ecosystems and hinders knowledge of the diversity and geographic distribution of global deep-sea corals. Therefore, it is crucial to conduct species identification and biodiversity surveys of deep-sea corals in the Indian Ocean.

During the 2022 survey of the benthic biodiversity at the Carlsberg Ridge in the Indian Ocean, two specimens of deep-sea precious corals were collected. This study aims to enrich the information on deep-sea coral species through morphological taxonomic identification and molecular phylogenetic analysis of these two red corals, addressing the significant gap in the discovery of new species in the Indian Mid-ocean ridge ecosystems.

Materials and methods

Specimen collection and morphological analyses

The specimens were collected by the *Jiaolong* Human-Operated Vehicle (HOV) from the Guangde Ridge in the western Indian Ocean in 2022 at coordinates 3.444°N, 64.101°E (Fig. 1). These specimens were photographed in situ before being sampled and photographed again on board. To maximise the protection of the coral habitat without causing damage, some coral samples were collected by taking only branches or by recording videos (see Fig. 2 and Suppl. materials 1–5). Small branchlets with a few polyps were stored at -80 °C for DNA extraction. The remaining larger branches were fixed in 70% ethanol at -20 °C for morphological study.

The number of autozooids and branches, as well as their colour and branching arrangement, were examined by the naked eye. The branches, axis and polyps of the specimens were examined and photographed using a microscope Nikon SMZ1270. Measurements of the diameter of the axis and branches and the spacing, width and height of autozooids were taken using ImageJ software (https://imagej.net/ij/). The specimens were dissected using dissecting needles and scalpels into two parts: the axis with coenenchyme covered and the autozooids. These parts were soaked in a 10% sodium hypochlorite solution for 1–2 hours separately until the soft tissues were completely dissolved. The resulting sclerites were cleaned with distilled water and anhydrous ethanol, then placed on double-sided insulating tape, which included the autozooids and the axis. After drying, the samples were gold-sprayed and observed under a ZEISS GeminiSEM 360 scanning electron microscope for imaging.

The sclerites of the Corallioidae were classified according to standard taxonomic conventions (Bayer 1956; Bayer et al. 1983; Tu et al. 2012, 2016; Li and Xu 2023). Sclerite morphology is categorised into basic forms such as rods, radiates and irregular shape. Rods vary in length with surfaces that have small protrusions that are either sharp (Fig. 3a) or blunt (Fig. 3b). Crosses vary in angle and size (Fig. 3c). Different types of radiates vary in the number of their rays and the directions of the rays are roughly as shown in Fig. 3k. If either R1 or R8 is missing, it becomes a 7-radiate structure (Fig. 3e). If both R1 and R8 are missing, it becomes a 6-radiate structure (Fig. 3d). Additionally, the diagram shows that R3, R4,and R5, R6, R7 are asymmetrical, but in some 6- or 7-radiates, they are symmetrical. The projections of the rays on 8-radiates also differ morphologically, such as being closely spaced (Fig. 3f) or loosely spaced (Fig. 3g). Some 8-radiates' rays enlarge to form globular double clubs as mentioned in this study (Fig. 3h–g). Measurements of sclerite size were also conducted using Image J software.

DNA extraction and sequencing

Genomic DNA was extracted from the polyps using the MicroElute Genomic DNA Kit (OMEGA, USA) following the manufacturer's instructions. DNA concentration was calculated as: [DNA] = (Absorbance 260) × (0.05pg/μl) × (Dilution factor). The quality of DNA can be assessed by measuring absorbance at both 260 mm and at 280 nm. A ratio of (A_{260}/A_{280}) of 1.7–1.9 corresponds to 85%–95% purity. Four mitochondrial regions – NADH dehydrogenase subunit 1 (ND1), IGR1 (the intergenic region between ND6–COI region) and MSH (MutS-like protein) as described by Tu et al. (2015) – and 16S rRNA (16S) as described by France et al. (1996) were amplified for the coral samples (Table 1). PCR reactions were conducted in a total volume of 25 μl, comprising 1 μl of each primer, 9.5 μl of distilled H_2O, 12.5 μl of 2× Taq PCR Master Mix (with blue dye, Sangon) and 1 μl of the template DNA. The PCR products

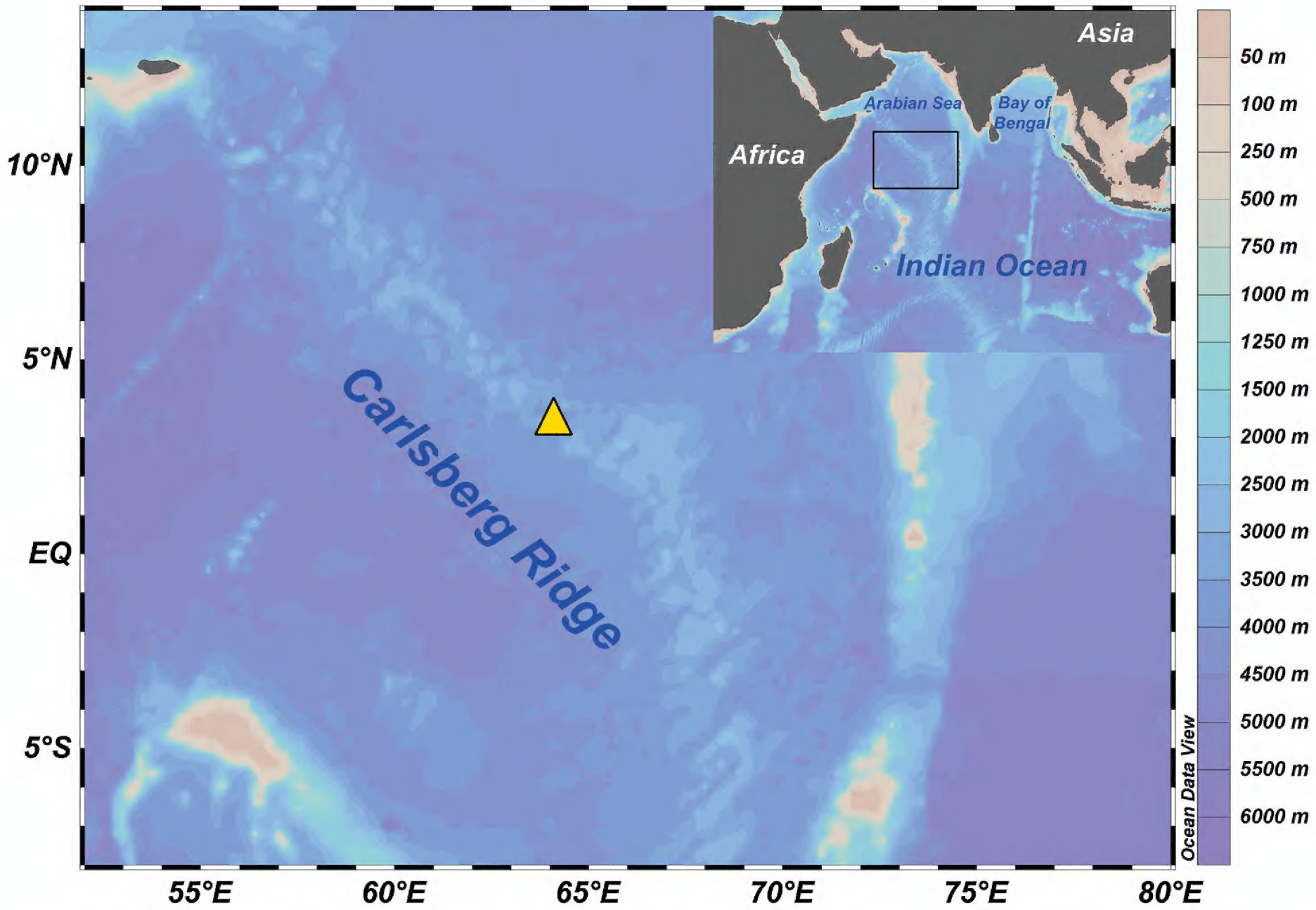

Figure 1. Collection regions of corals from the Carlsberg Ridge in the northern Indian Ocean in 2022. The square in the inset map indicates the area covered by the main map. The yellow triangle marks the location of the sampling station in this study. The colour gradient represents seawater depth. This map was created using Ocean Data View V.5.7.1 (https://odv.awi.de).

Table 1. Primers and PCR conditions used in this Study for *Hemicorallium* samples NADH dehydrogenase subunit 1 (ND1), IGR1 (the intergenic region between ND6–COI region) and MSH (MutS-like protein) were described by Tu et al. (2015); 16S rRNA (16S) was described by France et al. (1996).

Region	Primer	Sequence (5'-3')	PCR profile
ND1	ND1-Co-F	AAGAGTAGGCTATTCGCCCAAT	94 °C: 120s; (94 °C: 60 s; 45 °C: 60 s; 72 °C: 90 s) × 32
	ND1-Co-R	ATCACAGGACGTTCAAATAA	
IGR1	IGR1-Co-F	GAGATGACAGACGGTAAAGG	94 °C: 120s; (94 °C: 60 s; 45 °C: 60 s; 72 °C: 90 s) × 32
	IGR1-Co-R	GCCATTCGGAAGAAATGCT	
MSH	MSH-Co-F	ACACGGGAGATCAGATACTCTCAG	94 °C: 120s; (94 °C: 60 s; 51 °C: 60 s; 72 °C: 90 s) × 32
	MSH-Co-R	TAGAAGAGCAGATTCCATGAAGG	
16S rRNA	Octo1-L	AAACCCATCAGGTTTTACTGG	94 °C: 120s; (94 °C: 30 s; 45 °C: 60 s; 72 °C: 180 s) × 30
	Octo2-H	CGATAAGAACTCTCCGACATATA	

were sequenced in both directions by Sanger sequencing at Sangon Biotech, Inc. (Qingdao, China) using the same primers as in the amplification reaction. The sequenced fragments obtained from bidirectional sequencing were assembled using Dnastar Lasergene v.7.1 (Clewley 1995). Discrepancies between the forward and reverse reads were manually checked by inspecting chromatograms and resolved, based on the highest quality base calls. Sequences with Phred quality scores above 20 were considered reliable and those with lower scores were excluded or re-sequenced. All sequences from the two specimens in this study were deposited in the GenBank database (see Suppl. material 6).

Phylogenetic analyses

In the NCBI database, four mitochondrial genes from 19 species across four genera (*Corallium*, *Hemicorallium*, *Pleurocorallium* from Tu et al. (2015) and *Paragorgia* from Figueroa and Baco (2014) and Li et al. (2021)) were selected for phylogenetic analysis. These genera belong to the family Coralliidae (order Alcyonacea), which includes species closely related to those studied in this work. An outgroup species, *Chrysogorgia tricaulis* Duchassaing & Michelotti, 1864 from a different family (Chrysogorgiidae Verrill, 1883), was included due to its phylogenetic

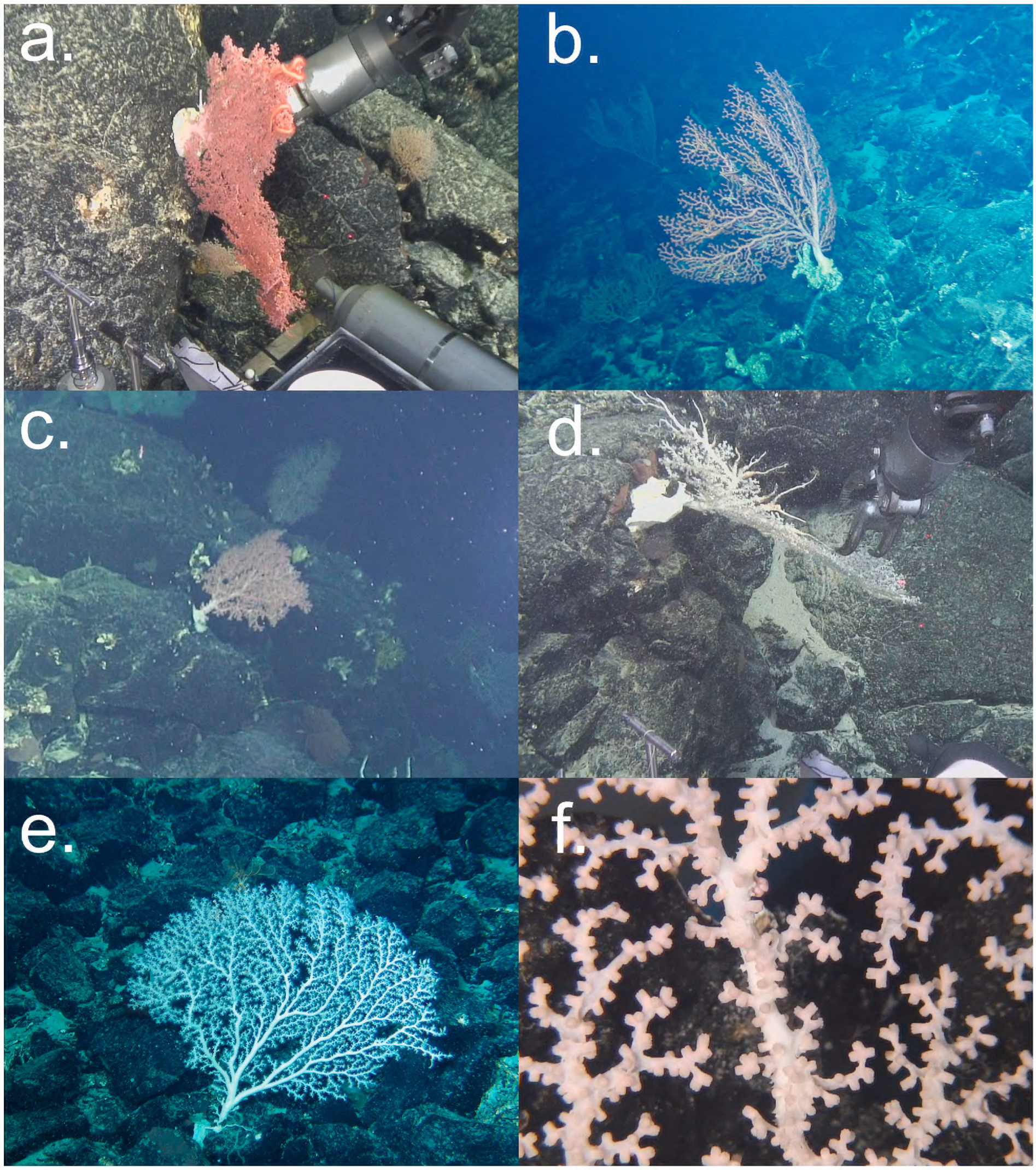

Figure 2. In-situ images of deep-sea corals samples in this study. These images are from in-situ video screenshots and the camera on the *Jiaolong*. **a.** Sample in situ image of FIO-IND72-JLBEN22003; **b.** Sample in situ image of NDSC-IND72-JLBEN22001; **c.** Coral in the same area that was highly similar to FIO-IND72-JLBEN22003; **d.** Sample in situ image of FIO-IND72-JLBEN22005; **e, f.** Coral in the same area that was highly similar to FIO-IND72-JLBEN22005.

distance from the target genera, serving as a reference for rooting the phylogenetic tree. The two specimens from this study were also included in the analysis. All GenBank accession numbers are available in Suppl. material 6. The sequences were aligned and trimmed using the ClustalW algorithm (Thompson et al. 1994) and then concatenated in MEGA v.7 (Kumar et al. 2016) with lengths of 16S at 334 bp, IGR1 at 570 bp, MSH at 595 bp and ND1 at 726 bp. Phylogenetic trees were reconstructed from the resulting concatenated sequence alignment using both the Bayesian Inference (BI) method and Maximum Likelihood (ML) analysis to ensure the robustness of the phylogenetic conclusions. For Bayesian Inference, we used the MrBayes version 3.1.2 (Ronquist et al. 2012). ModelFinder v.2.2.0 was used to select the best-fit model based on the BIC criterion (Kalyaanamoorthy et al. 2017), which identified

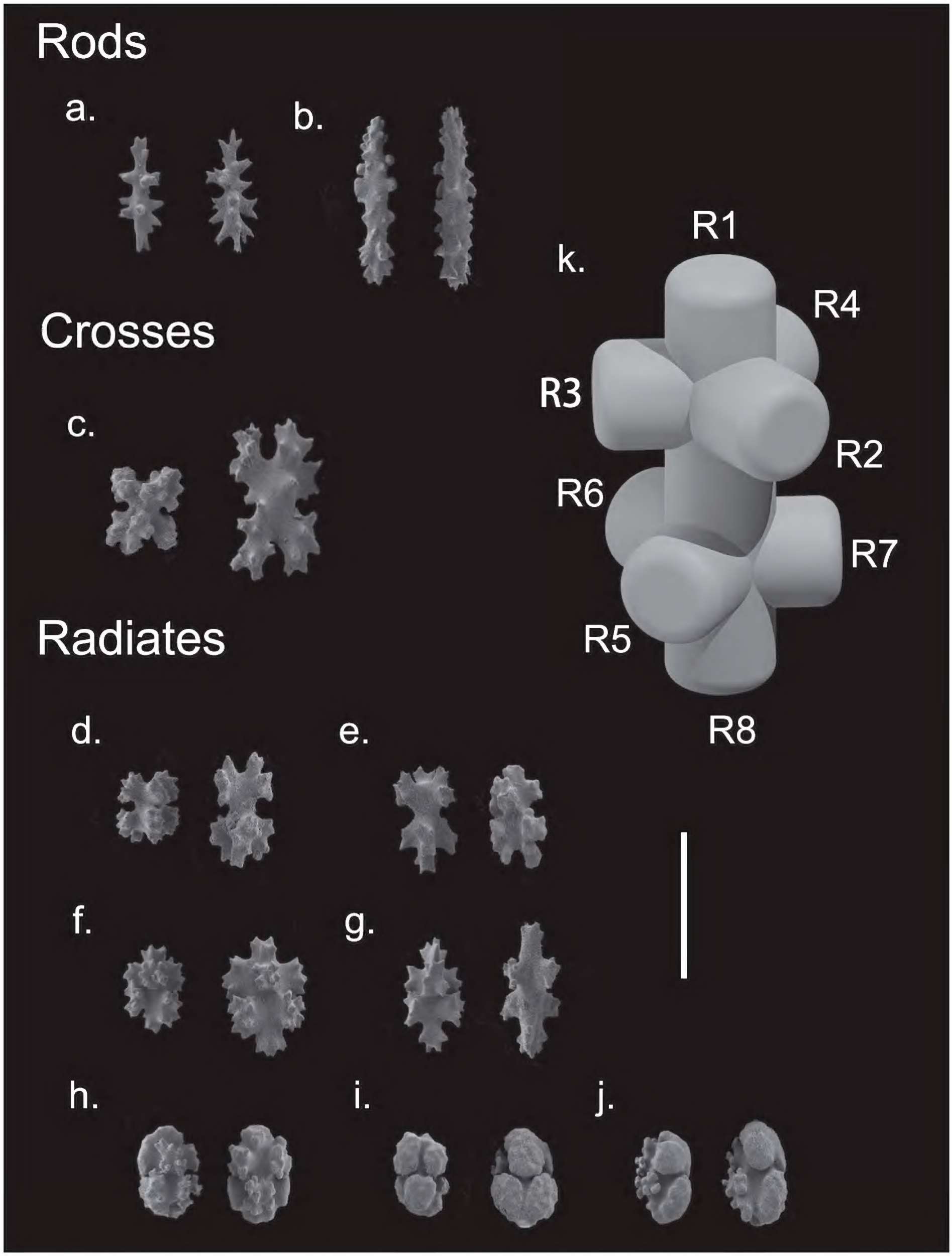

Figure 3. Morphology of sclerites involved in this study and the diagram of radiates. **a.** Rods with sharp protrusions; **b.** Rods with blunt protrusions; **c.** Crosses; **d.** 6-radiates; **e.** 7-radiates; **f.** 8-radiates with the rays closely spaced; **g.** 8-radiates with the rays loosely spaced; **h.** The multilobular ornaments face of the double clubs; **i.** The enlarged rays face of the double clubs; **j.** The side view of the double clubs (both showing multilobular ornaments and enlarged rays); **k.** A simple diagram of 8-radiates to show the direction of the eight rays, generated using the visualisation modelling software Sharp3D (version 5.661). Scale bar: 100 μm (**a–j**).

HKY+F+G4 as the best-fit model. The Markov-Chain Monte Carlo (MCMC) process was run with four chains for 2,000,000 generations, with trees being sampled every 100 generations. The first 500 trees were discarded as burn-in. For Maximum Likelihood analysis, we used IQ-TREE v.2.2.0 (Nguyen et al. 2015), under the HKY+G4+F model. The analysis was run with 1000 ultrafast bootstraps to assess the support for the tree topology (Minh et al. 2013). Both Bayesian Inference and Maximum Likelihood methods produced consistent results, which further strengthens the reliability of the phylogenetic tree.

Date resources

The data underpinning the analysis reported in this paper are deposited at ZooBank, the International Commission on Zoological Nomenclature's official registry for zoological nomenclature.

Results

Morphological taxonomy

Systematics

Class Octocorallia Haeckel, 1866
Order Scleralcyonacea McFadden, van Ofwegen & Quattrini, 2022
Famliy Coralliidae Lamouroux, 1812

Genus *Hemicorallium* Gray, 1867

Hemicorallium Gray, 1867: 126; Ridley 1882: 222; Johnson 1899: 59; Kükenthal 1924: 47; Bayer 1956: 74; Bayer 1964: 467; Bayer and Cairns 2003: 222; Ardila et al. 2012: 254; Figueroa and Baco 2014: 83; Tu et al. 2015a: 302; 2015b:173; 2016; 1010–1011; Horvath, E. A. 2019: 28.

Type species. *Hemicorallium tricolor* Johnson, 1899.

Diagnosis. Modified from Tu et al. (2016) and Nonaka and Hayashibara (2021). Polyps are dimorphic, consisting of autozooids and siphonozooids. Autozooids are prominent, oval and usually distributed on one side of the colony. When contracted, the autozooids cannot fully retract into the cortex. Siphonozooids are fertile, usually inconspicuous or appear as papillae and are distributed near the base of autozooids. Sclerites include small rods, crosses, 6-, 7- and 8-radiates; double clubs are only present in some species and vary in shape. Long rods or spindles are usually present in tentacles.

Hemicorallium indicodensum Hu, Zhang & Xu, sp. nov.

https://zoobank.org/0327FA15-493E-47D9-8FBC-4FECDF213FAC

Material examined. ***Holotype*** • part of a colony branch with a broken edge on the stem; collected from the Guangde Ridge in the western India Ocean on 13 June 2022; Located at 3°26'39.35"N, 64°6'3.06"E, depth 1697 m; currently preserved at -20 °C in the Key Laboratory of Marine Eco-Environmental Science and Technology, First Institute of Oceanography, China with voucher number FIO-IND72-JLBEN22003. ***Paratype*** • A colony from the base of the main stem to the branches, but missing the top branches. Collected from the Guangde Ridge in the western Indian Ocean on 13 June 2022; Located at 3°26'30.31"N, 64°6'6.40"E, depth 1697 m; currently preserved in alcohol at the China National Deep Sea Center with NDSC-IND72-JLBEN22001.

Description. ***Colony.*** The specimen FIO-IND72-JLBEN22003 is part of a colony, nearly 22 cm in height and the thickest stem is less than 1cm in diameter (Fig. 4a). Two main branches exhibit dichotomous branching in one plane with an acute angle. The branchlets are abundant and mostly arranged in an irregular pinnate pattern on one plane. Some of them grow at an acute angle, resulting in closely-spaced and overlapping branchlets. A brittle star is entwined amongst the branches. Paratype NDSC-IND72-JLBEN22001 retained only the white basal part and the thicker lower branches (Fig. 4i). The branches are light red, with the colour becoming paler towards the base. Small branches with autozooids are distributed across half of the colony's plane.

Polys. The autozooids are cylindrical and non-retracted, distributed on one side of the colony and are mostly alternately arranged on the branchlets (Fig. 4b). At the tips of the branchlets, two symmetrical autozooids form a Y-shape. Autozooids are 2.483 ± 0.348 mm in height and 1.515 ± 0.174 mm in width. They are abundant with most branchlets hosting fifteen or more. Each autozooid features eight longitudinal grooves that extend from the tentacle tips about two-thirds down to the base (Fig. 4d). Siphonozooids form subtle protrusions on the cortex.

Axis. The axis is solid and rigid, with no presence of canals inside (Fig. 4c and Suppl. materials 7–9). It is covered by yellowish mesoglea tissue between the axis and the cortex (coenenchyme). The surface of the axis is uneven (Fig. 4f), featuring irregular, sharp, thorn-like projections (Fig. 4d).

Colour. In underwater in situ videos, it appears light pink. The base of the colony is white. The fresh coenenchyme and polyps are pale red, turning pink when dried. Specimens preserved in alcohol retain a pale red colour. The axis is red and sclerites observed under a microscope appear pale red.

Sclerites. The predominant sclerite type in this species is the distinctive double clubs (65.720 ± 5.630 μm in length, Fig. 5d, e), constituting about 70% of all radiate sclerites (21/30 from tentacles, 24/33 from coenenchyme). This double club shapes are quite special, typically derived from 8-radiates. According to the model of radiates (Fig. 3k), the R1, R4, R6, R7 and R8 of the 8-radiates in this specimen are enlarged to form smoother and more globular rays, while the R2, R3 and R5 remain smaller with multilobular ornaments. Due to the fusion of rays, some double clubs cannot identify their termi-

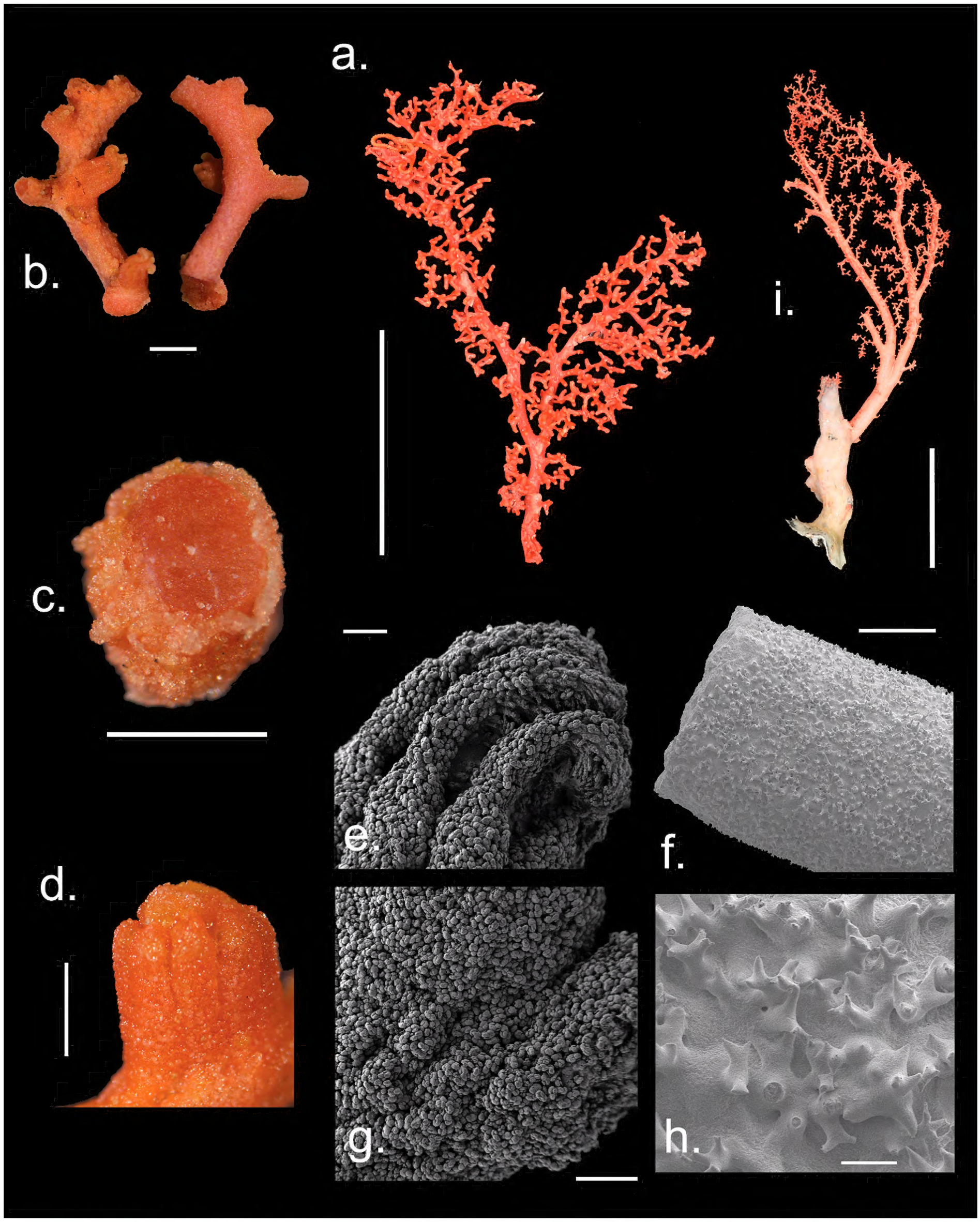

Figure 4. Morphological observation of *Hemicorallium indicodensum* sp. nov. FIO-IND72-JLBEN22003 collected in the western India Ocean. Photographs by camera (**a**); Microscopic observations(**b–d**); Scanning Electron Microscope (SEM) observations (**e–h**). **a.** The holotype of *H. indicodensum* sp. nov. FIO-IND72-JLBEN22003; **b.** The front and back of a branch; **c.** The cross-section of the axis; **d.** The autozooid of *H. indicodensum* sp. nov.; **e.** The details of the tentacles at the end of an autozooid; **f.** The axis of *H. indicodensum* sp. nov.; **g.** The cortex of the autozooid and axis; **h.** The surface details of the axis; **i.** The paratype of *H. indicodensum* sp. nov. NDSC-IND72-JLBEN22001. Scale bars: 10 cm (**a, i**); 2 mm (**b**); 1 mm (**c, d**); 200 μm (**e**); 250 μm (**f**); 300 μm (**g**); 20 μm (**h**).

nal rays (R1, R8), making it uncertain whether they are derived from 8-radiates (maybe 6-, 7-radiates). A few radiate sclerites may be in the process of developing where the rays become more globular (Fig. 5f).

A few 6-, 7- or 8-radiates (not double clubs) are found in the coenenchyme with 74.520 ± 5.213 μm (Fig. 5g) and they are less numerous compared to the double clubs. Rods are found only in the tentacles, with an average length of 113.211 ± 9.298 μm (Fig. 5a, b). Some thick rods are elongated multi-radiates with 108.878 ± 13.299 μm (Fig. 5c). The surface and both ends of the rods exhibit distinct irregular protrusions. Additionally, crosses (Fig. 5h) and asymmetric multi-radiates (Fig. 5i) are presented in the coenenchyme.

Variation. Paratype NDSC-IND72-JLBEN22001 showed more details about the lower half of the colony, especially the basal part. The base of main stem is thicker, with the thickest diameter reaching 2.229 cm (Fig. 4i). There are slightly fewer autozooids and branches than the terminal branches shown in holotype FIO-IND72-JLBEN22003.

Etymology. The specific name *indicodensum* is proposed for this new species. The name combines Indico, derived from "Indicus," the Latin term for the Indian Ocean, with densi- meaning "dense" in Latin. This nomenclature reflects both the origin of the species in the expansive Indian Ocean and its distinctive, densely branched appearance.

Comparison. The specimens FIO-IND72-JLBEN22003 and NDSC-IND72-JLBEN22001 have all its polyps distributed on one side of the colony, featuring non-retracted autozooids and rod-shaped sclerites in the tentacles. Therefore, these specimens conform to the description of the genus *Hemicorallium* and is classified under this genus.

H. indicodensum sp. nov. FIO-IND72-JLBEN22003 resembles *Hemicorallium bayeri* Simpson & Watling, 2011 (Simpson and Watling 2011) and *Hemicorallium niobe* Bayer, 1964 (Bayer 1964; Sampaio et al. 2009) in that they feature abundant branchlets and dense autozooids, with double clubs as the primary sclerite type. However, they can be distinguished from each other based on geographic location, colour and the morphology of their double clubs. *H. bayeri* and *H. niobe* are only recorded in the Pacific and the colour of both colony and axis is white to yellow, which is different from the new species. The double clubs of *H. bayeri* and *H. niobe* have enlarged rays with obvious blunt projections, which distinctly differ from the smoother and more globular rays of the double clubs in *H. indicodensum* sp. nov. According to Tu et al. (2016) and Nonaka and Hayashibara (2021), the smooth double clubs' morphologies are also found in *Hemicorallium ducale* Bayer, 1955 (Bayer 1955; Tu et al. 2016), *Hemicorallium abyssale* Bayer, 1965 (Bayer 1956; Tu et al. 2012; Nonaka and Hayashibara 2021) and *Hemicorallium maderense* Johnson, 1899 (Johnson 1899). However, *H. indicodensum* sp. nov. can be readily distinguished from these three species based on the predominant portion of double clubs. Besides, *H. abyssale* has double clubs with surfaces that are not completely smooth and *H. maderense*'s double clubs have the most thoroughly enlarged rays. For more information on morphology comparisons, see Table 2.

In summary, the remarkable morphological features that distinguish this new species from other members of the genus *Hemicorallium* include:

1. Abundant branchlets bearing numerous and dense autozooids (> 2 mm).
2. An uneven surface on the axis, characterised by dense, fine and slightly sharp projections.
3. A predominance of globular double clubs sclerites (about 70%), which are mostly derived from 8-radiates and some of their enlarged rays possess a smooth, globular surface.

Remarks. *H. indicodensum* sp. nov. represents a new species of Coralliidae first recorded in the Indian Ocean. In addition to holotype FIO-IND72-JLBEN22003 and paratype NDSC-IND72-JLBEN22001, another highly similar *Hemicorallium* coral was found during a dive in the same area (Fig. 2c and Suppl. material 3). Due to the rarity of deep-sea samples, the coral was not collected for conservation purposes, but in situ videos suggest it belongs to the same species because its branchlets are extremely dense and numerous. This indicates that *H. indicodensum* sp. nov. is commonly distributed on the Guangde Ridge.

Hemicorallium jiaolongensis Hu, Zhang & Xu, sp. nov.

https://zoobank.org/DCE0B1DB-EC3A-4E32-A7AF-6EEAE78B6A6C

Material examined. ***Holotype*** • Partial colony consisting of a branch with a broken edge on the stem; collected from the Carlsberg Ridge in the western India Ocean on 13 June 2022; Located at 3°26'33.72"N, 64°6'2.75"E, depth 1696 m. Currently preserved at -20 °C in the Key Laboratory of Marine Eco-Environmental Science and Technology, First Institute of Oceanography, China with voucher number FIO-IND72-JLBEN22005. Due to the uncontrollable nature of deep-sea sample collection and preservation, a more detailed examination of another suspected sample could not be performed (Fig. 2f–h) and, therefore, no paratype was identified.

Description. ***Colony***. The specimen FIO-IND72-JLBEN22005 is a branch of the colony, approximately 22 cm tall, with the base being the thickest at about 0.6 cm in diameter (Fig. 6a). All branches present dichotomous branching on one plane. The branches are slightly curved, with many thinner branchlets appearing. There are remains of tissue where a brittle star had been entwined around the branches (the brittle star has been removed).

Polys. The branchlets can hold up to 14 non-retractable autozooids. At the tips of the branchlets, there are pairs of symmetrical polyps forming a Y-shape. These

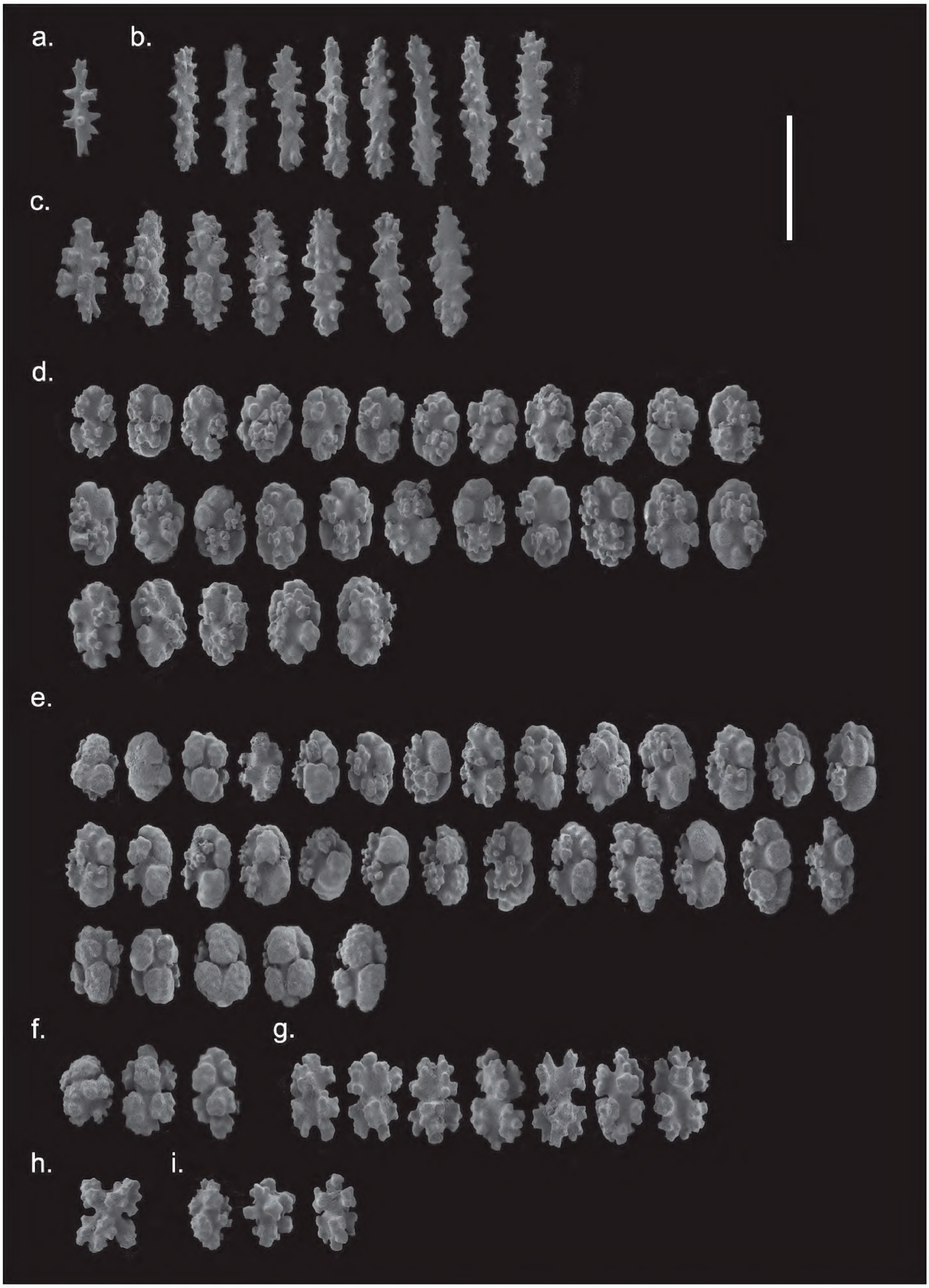

Figure 5. Morphological scanning electron microscopy observations of sclerites in *Hemicorallium indicodensum* sp. nov. **a, b.** Rods sclerites from the tentacles; **c.** Elongated radiates sclerites from the tentacles; **d.** Double clubs sclerites, showing the side with small multilobular ornaments and distributed in all parts; **e.** Double clubs sclerites, showing the side with smooth and globular rays and distributed in all parts; **f.** Radiates sclerites with rays becoming more globular at the ends, from autozooids; **g.** 6-, 7- or 8-radiates from the coenenchyme; **h.** Crosses sclerites from the coenenchyme; **i.** Irregular multi-radiates sclerites from the coenenchyme. Scale bar: 100 μm.

Table 2. Comparison of morphological characteristics between the two new species described and all other species of the genus *Hemicorallium*. "–" means not recorded; "Not sure" means ambiguity in different references.

Species	Coenenchyme		Axis colour	Autozooids height (mm)	Sclerites					Reference
	colour	surface			rods (mm)	6,7-radiates (mm)	8-radiates (mm)	double clubs	other	
H. indicodensum sp. nov.	red	conical papillae	red dish pink	abundant, 2.483 ± 0.348	0.113 ± 0.009	0.745 ± 0.005	globular double clubs; 0.657 ± 0.006	Present, surface smooth	elongated 8-radiates; double clubs abundant	this study
H. jiaolongensis sp. nov.	light yellow	no papillae	milky white	Abundant, 3.312 ± 0.554	short rods: 0.860 ± 0.015; long rods:0.113± 0.019	0.0658 to 0.093	0.059 to 0.1	absent	8-radiates with sharp spikes; rays tightly clustered together	this study
H. ducale	dark pink	small, hemispherical or irregular calyces	richer and deeper than the rind	less than 1.5	present	Up to 0.1		Present, surface rough; 0.060 to 0.085	show a considerable subdivision of the radii or are otherwise misshapen	Bayer (1955); Tu et al. (2016)
H. imperiale	rich pink	small, irregular verrucas	rich pink	2.5 tall, up to 3	0.10 to 0.11	–	0.08 to 0.1	absent	The existence of double clubs is controversial	Bayer (1955); Tu et al. (2016)
H. bathyrubrum	red	prominently papillate	deep pink to red	1.8–2 in height and 1.5–1.7 at the base	up to 0.119 in tentacle; up to 0.106 in pharyngeal	up to 0.070 for 6-radiates and up to 0.090 for 7-, 8-radiate and irregular forms		Present; surface rough	radiate-type sclerites bear slight resemblance to double clubs, but are not so highly modified	Simpson and Watling (2011)
H. bayeri	light pink to almost white	Small, raised bumps cover coenenchyme surface	completely white	up to 2.85	up to 0.115	up to 0.085		Present; surface rough	'Heads' of enlarged rays sculpted with pointed and more bluntly-shaped projections in double clubs	Simpson and Watling (2011)
H. sulcatum	Pale pink or orange	Smooth, with inconspicuous warts	Pale pink or pinkish	1.25	> 0.1	Contains 8-radiates mainly, irregular-shapes present		Not sure	The type-specimen is missing	Tu et al. 2012; Nonaka and Hayashibara (2021)
H. taiwanicum	Dark pink	Front side is thin and fragile; the dorsal side is smooth and not creased	orange	0.93 in height; 1.15 in wide	Up to 0.11	Up to 0.054 and 0.065	0.096	Present; surface rough	The tentacles are grey	Tu et al. (2012)

Species	Coenenchyme		Axis colour	Autozooids height (mm)	Sclerites					Reference
	colour	surface			rods (mm)	6,7-radiates (mm)	8-radiates (mm)	double clubs	other	
H. tricolor	Pale yellow cortex and vermilion-red autozooids	small raised bumps	Lightly pink to white	up to 2.43	Up to 0.115	Up to 0.052	Up to 0.056	Present 0.055	Double clubs account for 3%	Johnson (1899); Tu et al. (2015)
H. variabile	Rosy, red with a yellowish-brown coenenchyme			0.06 to 0.08	From 0.06 to 0.09	Resemble opera-glasses in shape; 0.06 in length and 0.04 in width		Present; surface rough	No clear picture information	Thomson et al. (1906); Tu et al. (2016)
H. kaiyo	dry: pale red	smooth, no warts	deeper red colour	1.00 ± 0.19 in height	0.102 ± 0.014	autozooid: 0.058 ± 0.008 (6); 0.062 ± 0.009 (7); branch tips: 0.058 ± 0.006 (6); 0.057 ± 0.008 (7);coenenchyme: 0.053 ± 0.006 (6,7)	autozooid: 0.068 ± 0.011; branch tips: 0.061 ± 0.006; coenenchyme: 0.059 ± 0.006	absent	both symmetric and asymmetric 8-radiates	Nonaka and Hayashibara (2021)
H. meraboshi	pale pink on branch: bright red on autozooid mounds	inconspicuous siphonozooids	white	1.66 ± 0.35 in height	0.142 ± 0.019	present, but a few	autozooid: 0.094 ± 0.008; branch tips: 0.081 ± 0.008; coenenchyme: 0.077 ± 0.004	absent	large (over 0.1mm long) multi-radiate sclerites	Nonaka et al. (2023)
H. muzikae	dry: pale pink	warts (about 0.23 mm) are visible	deeper pink colour	0.99 ± 0.20 in height	0.092 ± 0.017	autozooid: 0.065 ± 0.003 (7); coenenchyme: 0.056 ± 0.006 (7)	autozooid: 0.068 ± 0.008; branch tips: 0.059 ± 0.009; coenenchyme: 0.058 ± 0.005	absent	8-radiates dominant	Nonaka and Hayashibara (2021)
H. tokiyasui	dry: pale pink, some twigs are whitish to white	Small but distinct warts	pale purple to pink	1.10 ± 0.26 in height	0.077 ± 0.011	branch tips: 0.044 ± 0.004 (6); coenenchyme: 0.044 ± 0.004 (6); 0.046 ± 0.005 (7)	autozooid: 0.060 ± 0.009; branch tips: 0.047 ± 0.005; coenenchyme: 0.048 ± 0.003	absent	except for the tentacle rods, the sclerites are smaller	Nonaka and Hayashibara (2021)
H. abyssale	pink	prominent papillae	red	1.76 ± 0.43	0.106 ± 0.019	0.050 to 0.071	0.050 to 0.130	Present, surface smooth	asymmetric multi-radiates	Bayer (1956); Nonaka and Hayashibara (2021)
H. aurantiacum	dark pinkish-orange	papillae	pale pink to white	1.3 to 1.7	–	0.040 to 0.060	0.056 to 0.080	absent	both spherical and symmetrical 8-radiates present	Hickson and Versluys (1907); Tu et al. (2016)
H. guttatum	Yellowish-white	protuberance	milk white	1.7 to 2.2	–	0.042 to 0.078	0.062 to 0.090	absent	Asymmetry and spherical multi-radiates	Tu et al. (2016)

Species	Coenenchyme		Axis colour	Autozooids height (mm)	Sclerites					Reference
	colour	surface			rods (mm)	6,7-radiates (mm)	8-radiates (mm)	double clubs	other	
H. halmaheirense	orange red	scraggy	orange red	2 to 3	0.075 to 0.118	–	0.035 to 0.081	absent	spherical 8-radiates present	Hickson and Versluys (1907); Tu et al. (2016)
H. laauense	white	conical papillae	white	1.14 ± 0.19	0.122 ± 0.014	–	0.060 to 0.091	absent	elongated 8-radiates (0.1mm)	Bayer (1956); Nonaka and Hayashibara (2021)
H. niobe	white in ethanol	no papillae	white in ethanol	0.94–1.0	–	0.050 to 0.060	0.055 to 0.085	absent	elongated 8-radiates	Tu et al. (2015)
H. regale	pale pink	no papillae	pink to pale red	1.36	0.075 ± 0.014	0.051 to 0.067	0.061 ± 0.008	absent	a few 8-radiates in autozooids, spherical 6-radiates	Bayer (1956); Nonaka and Hayashibara (2021)
H. reginae	light orange	no papillae	orange to red	1.3 to 1.5	up to 0.106	0.050 to 0.071	0.053 to 0.081	present	vary in spherical and symmetrical 8-radiates present	Hickson and Versluys (1907); Tu et al. (2016)
H. maderense	–	–	–	–	Present	–		Present; surface smooth	Present spherical radiates	Johnson (1899); Tu et al. (2016)
H. boshuense	–	–	–	–	present	Present irregular and large sclerites		Not sure	Type specimen described by Kishinouye is missing; Closely resembles *H. sulcatum*	Nonaka and Muzik (2007)

autozooids are distributed only on one side of the colony, with some forming acute angles or being perpendicular to the plane of the colony (Fig. 6b). The autozooids are 3.312 ± 0.554 mm in height and 1.759 ± 0.147 mm in width, the height of them usually being greater than the distance between them. Siphonozooids are not easily observed and appear as tiny pores on the branches.

Axis. The surface of the coenenchyme is uneven, but lacks noticeable protrusions or depressions. The side without autozooids has slight longitudinal grooves (Fig. 6b). The axis is hard calcareous with no presence of canals inside (Fig. 6c and Suppl. materials 7–9). The surface of the axis without coenenchyme reveals irregular, sharp projections (Fig. 6h).

Colour. In underwater in situ videos, it appears white to light yellow. The base of the colony is white. After being collected and brought on board, the fresh coenenchyme is light yellow. The axis exhibits a translucent milky white appearance (Fig. 6c) and sclerites observed under a microscope appear pale red.

Sclerites. Rods are mainly present in the tentacles and there are two main types: short rods with sharp and large radial projections (86.028 ± 15.155 µm in height, Fig. 7a) and long rods with small and blunt projections (112.769 ± 19.156 µm in height, Fig. 7b). Both types of rods have irregular small protrusions at both ends.

Crosses, 6-, 7- and 8-radiates and irregular radiates are found in both the autozooids and the axis surface (coenenchyme). Crosses sclerites are rare (Fig. 7c) and only two sclerites were captured with different crossing angles. They measured 88.388 µm in height and 107.593 µm in width with nearly 90° angles and 73.350 µm in height and 60.283 µm in width with nearly 60° angles, respectively. The 6- and 7-radiates can be either symmetrical or asymmetrical (Fig. 7d), measuring approximately 65.837 µm to 92.7717 µm in length. The 8-radiates are the most abundant, with two different types. The ends of the rays in a particular type of 8-radiates consist of multiple sharp spikes (72.452 ± 8.572 µm in height, Fig. 7e). They have larger rays and gaps between them are hard to discern due to R2, R3, R4 and R5, R6 and R7 being tightly clustered together. Other 8-radiates have smaller, but more pronounced rays with spaces between the eight rays (80.418 ± 10.907 µm in height, Fig. 7f). The irregular radiates (Fig. 7i) are about 45.257 µm to 103.113 µm in height and typically feature asymmetric shapes or excessively protruding rays. No double clubs have been found in this specimen.

Etymology. This species, *Hemicorallium jiaolongensis*, is named in recognition of the manned submersible "*Jiaolong*", which was instrumental in the collection of this specimens. The name honours the dedication and efforts of the Jiaolong crew during the scientific expedition in the western Indian Ocean.

Comparison. Specimen *H. jiaolongensis* sp. nov. FIO-IND72-JLBEN22005 exhibits all its polyps distributed on one side of the colony, with non-retracted autozooids and rod-shaped sclerites present in the tentacles. Therefore, this specimen aligns with the characteristics of the genus *Hemicorallium* and is classified within this genus.

The newly-described *H. jiaolongensis* sp. nov. features a distinct type of 8-radiates that differentiates it from the closely-related *Hemicorallium laauense* Bayer, 1956 (Bayer 1956; Tu et al. 2012; Nonaka and Hayashibara 2021), which also lacks double clubs. The rays of these 8-radiates have sharp spikes at their ends. More notably, the gaps between the rays, except for R1 and R8, are very small, making the gaps between the rays hard to discern. In previously-recorded species of the genus *Hemicorallium*, the edges of the 8-radiates typically have blunt spikes and clear gaps can be observed between the upper and lower halves (similar to those in Fig. 3f). Compared to all other reported species of the *Hemicorallium* genus that lack double clubs, *H. jiaolongensis* sp. nov. can be distinguished by its absence of spherical radiates which are present in *Hemicorallium aurantiacum* Tu, Dai & Jeng, 2016 (Tu et al. 2016), *Hemicorallium guttatum* Tu, Dai & Jeng, 2016 (Tu et al. 2016; Wei et al. 2024), *Hemicorallium halmaheirense* Hickson, 1907 (Hickson and Versluys 1907; Tu et al. 2016), *Hemicorallium imperiale* Bayer, 1955 (Bayer 1955) and *Hemicorallium regale* Bayer, 1956 (Bayer 1956). *Hemicorallium Kaiyo* Nonaka & Hayashibara, 2021 (Nonaka and Hayashibara 2021) lacks rods with sharp projections and the crosses that are both present in *H. jiaolongensis* sp. nov. *Hemicorallium reginae* Hickson, 1905 (Koninklijke Akademie van 1905; Tu et al. 2016) and *Hemicorallium variabile* Thomson & Henderson, 1906 (Thomson et al. 1906) each possess their own unique irregular sclerites which are not found in *H. jiaolongensis* sp. nov. For more information on morphology comparisons, see Table 2.

In summary, the remarkable morphological features that distinguish this new species from other members of the genus *Hemicorallium* include:

1. The taller (about 3 cm) and closely-spaced autozooids.
2. An uneven surface on the axis, characterised by sparse, fine and slightly sharp projections.
3. A particular type of 8-radiates with sharp spikes on the edges and the middle rays of the radiates are tightly clustered together.

Remarks. *H. jiaolongensis* sp. nov. represents a new species of Coralliidae first recorded in the Indian Ocean. Although no paratype is available, the features of another coral specimen, as observed through in situ videos and photographs, are highly similar to the holotype (Fig. 2e–f and Suppl. material 5). This specimen also exhibits a white to light yellow colony with polyps distributed on one side. All small branches are numerous and densely packed.

Molecular phylogenetics

This study utilised four mitochondrial regions (16S, IGR1, MSH, ND1) concatenated for phylogenetic tree

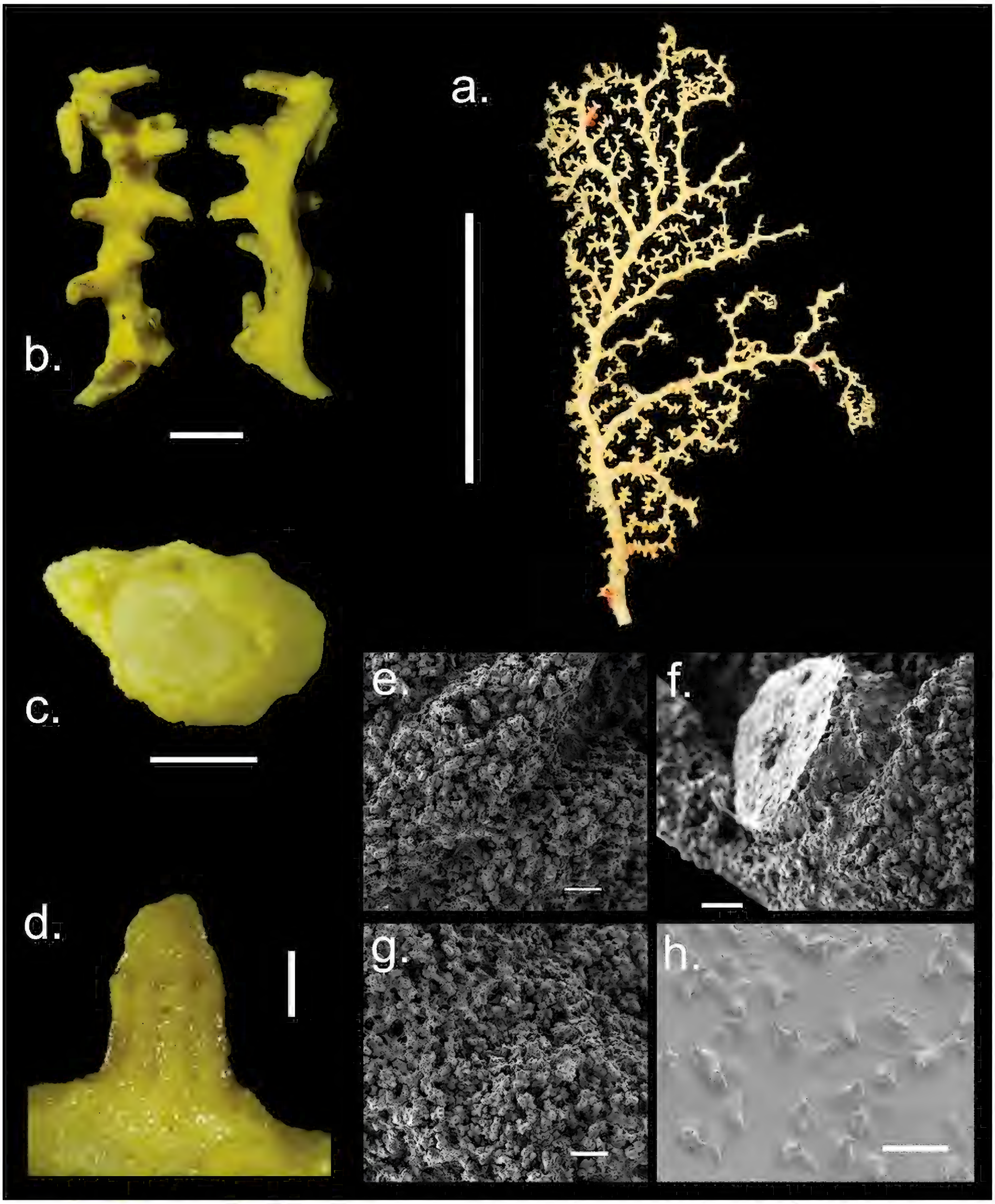

Figure 6. Morphological observation of *Hemicorallium jiaolongensis* sp. nov. FIO-IND72-JLBEN22005 collected in the western India Ocean. Photographs by camera (**a**); Microscopic observations (**b–d**); Scanning Electron Microscope (SEM) observations (**e–h**). **a.** The colony of *H. jiaolongensis* sp. nov.; **b.** The front and back of a branch; **c.** The cross-section of the axis; **d.** The autozooid of *H. jiaolongensis* sp. nov.; **e.** The details of the tentacles on an autozooid; **f.** The axis of *H. jiaolongensis* sp. nov.; **g.** The cortex of the axis; **h.** The surface details of the axis. Scale bar: 10 cm (**a**); 5 mm (**b**); 1 mm (**c, d**); 100 μm (**e, f**); 200 μm (**g**); 50 μm (**h**).

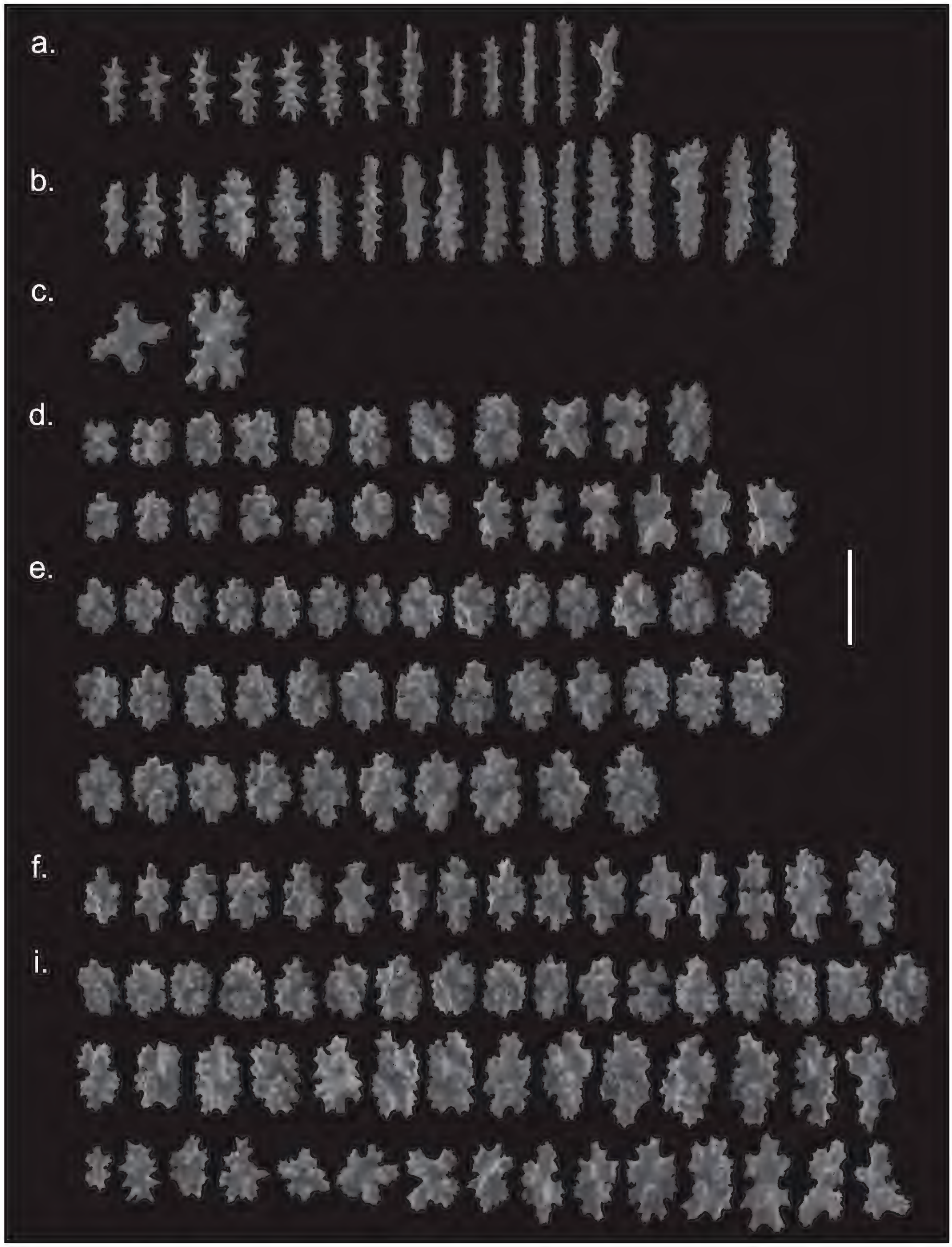

Figure 7. Morphological scanning electron microscopy observations of sclerites in *Hemicorallium jiaolongensis* sp. nov. **a, b.** Rods sclerites from the tentacles; **c.** Crosses sclerites; **d.** 6- and 7-radiates from both the autozooids and coenenchyme; **e, f.** 8-radiates from both the autozooids and coenenchyme; **g.** Some irregular multi-radiates sclerites. Scale bar: 100 μm.

construction using Bayesian Inference and Maximum Likelihood (ML) methods (Fig. 8). The resulting topologies from both BI and ML analyses were consistent, so only the Bayesian tree is shown. The posterior probabilities for BI and bootstrap values for ML are indicated near the branches. The phylogenetic tree supports the inclusion of the new species *H. indicodensum* sp. nov. and *H. jiaolongensis* sp. nov. within the *Hemicorallium* clade, consistent with the findings of Tu et al. (2015) and Nonaka et al. (2023). Additionally, the *Paragorgia* clade support the conclusion proposed by McFadden et al. (2022) that incorporating these groups into the family Coralliidae is appropriate.

The phylogenetic tree was constructed using a concatenated analysis of four genes: NADH dehydrogenase subunit 1 (ND1), IGR1 (the intergenic region between COI–ND6), MSH (MutS-like protein) and 16S rRNA (16S). The tree was generated using Bayesian Inference (BI) and Maximum Likelihood (ML) methods, with both analyses producing consistent topologies. Bayesian posterior probabilities (if > 90%) and ML bootstrap values (if > 70%) are shown at the nodes. The scale bar represents the number of substitutions per site.

Discussion and conclusions

New species of red corals in the Indian Ocean

This study has discovered two new species of deep-sea corals belonging to the genus *Hemicorallium*, collected from the Guangde Ridge in the south-eastern part of the Carlsberg Ridge in the Indian Ocean. The Guangde Ridge was named by the Chinese research vessel "*Shenhai Yihao*". Despite the absence of paratypes for *H. jiaolongensis* sp. nov. due to unavoidable factors in deep-sea biological sampling, in situ videos and photographs from the area provide images of *Hemicorallium* corals highly similar to the samples of the two new species (Fig. 2c, e, f and Suppl. materials 3, 5). Therefore, the Guangde Seamount is considered the habitat for the two newly-discovered species, *H. indicodensum* sp. nov. and H. *jiaolongensis* sp. nov.

The two new species exhibit distinct differences from existing corals in morphology. They both have more branches and a denser arrangement of autozooids compared to other species in the same genus. This characteristic is only similarly observed in *H. bayeri* from the Atlantic seamounts (Simpson and Watling 2011). However, the colonies of the new species in this study have a smaller height-to-width ratio, giving them a shorter and wider overall appearance. Additionally, in this study, *H. indicodensum* sp. nov. and *H. jiaolongensis* sp. nov. possess unique sclerite morphologies, with the former having a predominance of smooth-surfaced double clubs, while the latter exhibits two types of 8-radiates.

The integration of morphological and molecular phylogenetic analyses has continuously refined coral classification with the rapid development of molecular biology techniques in recent years (Figueroa and Baco 2014; McFadden et al. 2022). Currently, the distinction between the genus *Hemicorallium* and other genera within the Coralliidae family can be effectively made through molecular phylogenetics (Tu et al. 2015; Nonaka et al. 2023). However, distinguishing species within the genus *Hemicorallium* remains challenging. In this study, molecular phylogenetic results indicate that the two new species belong to the genus *Hemicorallium*. The genetic distances between species are not clearly defined, which is also evident in the phylogenetic trees presented by Nonaka and Hayashibara (2021). These phenomena may be due to the lack of extensive genetic data for deep-sea *Hemicorallium* corals worldwide, owing to technical limitations in deep-sea sampling. Additionally, nearly half of the currently identified *Hemicorallium* species have been determined solely based on morphological characteristics, particularly sclerite morphology, without the support of genetic data due to the limitations of past technologies. Moreover, there are species within the genus *Hemicorallium* with differences in sclerite morphology, but very close genetic distances in molecular phylogenetic analysis (Tu et al. 2015; Nonaka et al. 2023). Whether these should be revised to be considered the same species remains a challenging issue. As noted by Ocaña Vicente et al. (2022), genetic peculiarities in anthozoans may hinder the ability to resolve species boundaries using molecular data alone. This is particularly true for deep-sea species, where limited genetic data and sampling difficulties further complicate the classification process. These challenges highlight the need for integrating both morphological and genetic approaches to improve species delimitation in these groups.

The limitations of short genetic fragments in species identification may be addressed by advances in next-generation sequencing (NGS) technologies, which allow for the assembly of larger genomic regions (Takata et al. 2021; Gordon 2023). These technologies hold promise for overcoming some of the limitations associated with single-gene analyses and may lead to more definitive species classifications in future studies. Additionally, these challenges underscore the need for more comprehensive surveys of *Hemicorallium* corals from different geographic regions. Currently, most records of *Hemicorallium* corals are concentrated in the Pacific (Tu et al. 2016; Nonaka and Hayashibara 2021) and the Atlantic (Simpson and Watling 2011). This study reports the first discovery of two *Hemicorallium* species in the Indian Ocean, providing morphological and molecular phylogenetic data that will support future classification and identification of the genus.

Variations of double clubs

As more Coralliidae corals are reported, the morphology of double clubs has shown variation beyond the original definition proposed by Bayer (1956): double carafes or

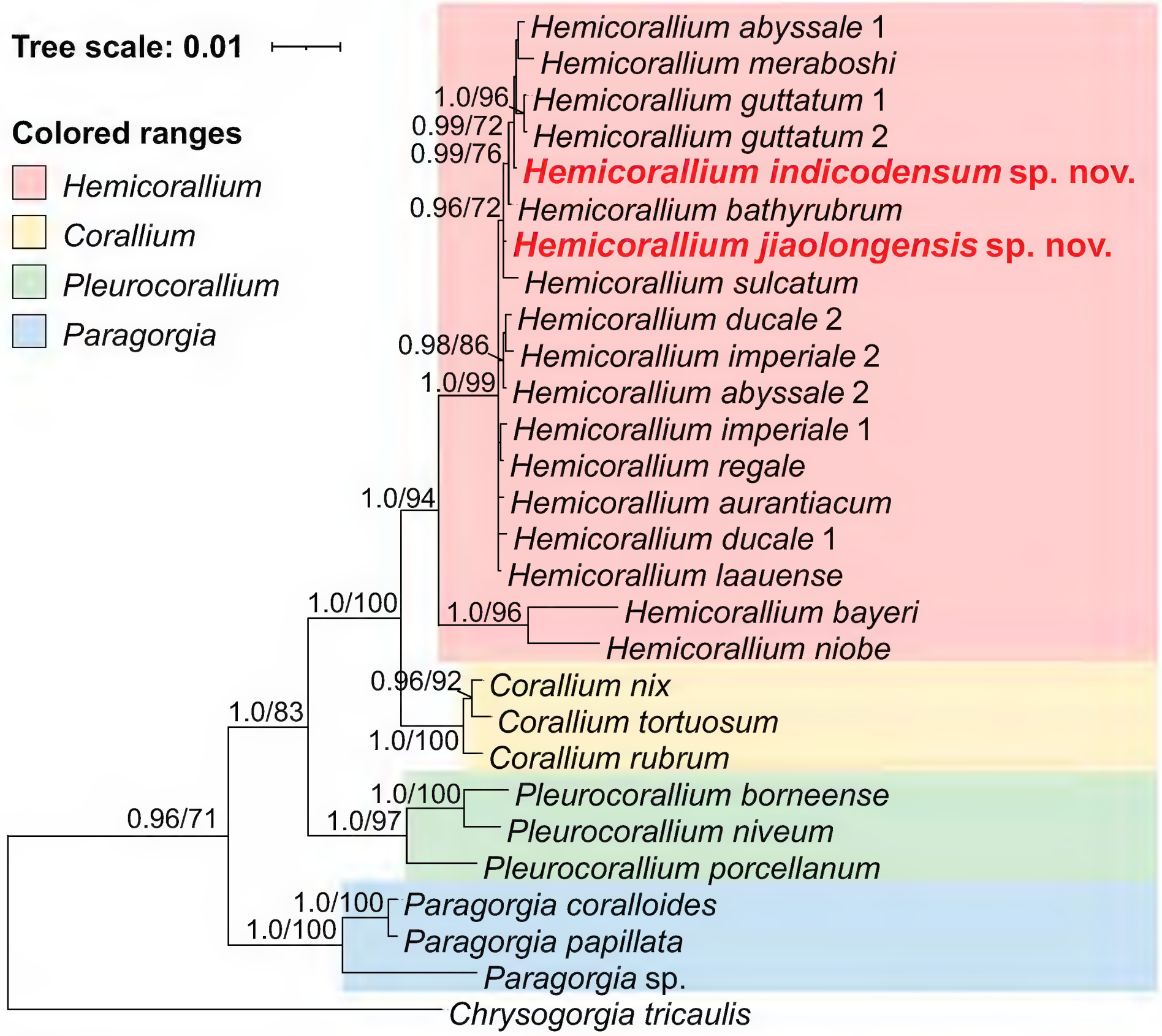

Figure 8. The phylogenetic tree of two new species of the family Coralliidae based on combined four-gene analysis.

opera glass spicules (Doppel Keulen). In this study, the unique and dominated radiate sclerites in *H. indicodensum* sp. nov. are defined as globular double clubs, which distinguish the new species from others. These globular double clubs are formed by the enlargement of rays on one side, which is the same as the formation of the original double clubs. However, the difference is that the globular double clubs in *H. indicodensum* sp. nov. are mostly developed from 8-radiates rather than the originally described 6-radiates and the enlarged portions have become more globular and smoother. Despite appearing quite different from the original definition of double clubs, the globular double clubs may represent a transitional form of double clubs. Therefore, we classify them as a variant of double clubs.

Other species in the genus *Hemicorallium* that possess double clubs significantly different from the original description include *H. niobe* (Bayer 1964; Sampaio et al. 2009), *H. ducale* (Bayer 1955; Tu et al. 2016) and *H. abyssale* (Bayer 1956; Tu et al. 2012; Nonaka and Hayashibara 2021). Similar double clubs have also been found in *Paragorgia coralloides*, but they were described as globular 8-radiate (Sánchez 2005). This also supports the inclusion of the genus *Paragorgia* into the family Coralliidae, based on sclerite morphology, aligning with the taxonomic results of Coralliidae reconstructed through phylogenetic analysis by McFadden et al. (2022). Interestingly, double clubs that closely resemble the original description are mostly found in the genera *Corallium* and *Pleurocorallium* (Tu et al. 2012, 2016), whereas, in *Hemicorallium*, they only appear in *H. tricolor* (Tu et al. 2015) and *H. maderense* (Johnson 1899).

The challenge of the red corals morphology

The morphology of red corals remains the primary and essential basis for their classification, with many studies still relying solely on morphological characteristics

for the taxonomy of the family Coralliidae (Simpson and Watling 2011; Tu et al. 2016). The challenge of morphological classification for red corals lies in the difficulty in distinguishing subtle differences in sclerite morphology, as well as variations in colony structure. These distinctions can often blur the lines between species, making it hard to determine whether observed variations fall within intraspecific variability or represent differences between species. Moreover, the rarity of some species and the difficulty in obtaining complete deep-sea specimens limit the scope of morphological studies, resulting in a reliance on partial data for classification (Table 2).

Based on the results of this study, extensive sclerite observation is crucial. It helps eliminate errors and estimate the proportion of different sclerite types, as noted in Nonaka and Hayashibara (2021) and Nonaka et al. (2023). For instance, both *H. indicodensum* sp. nov. and *H. abyssale* (Bayer 1956; Tu et al. 2012; Nonaka and Hayashibara 2021) have double clubs with a smooth surface that appear very similar. However, these sclerites in the new species are predominant in quantity (70%), a conclusion derived from extensive sclerite observation in this study. Additionally, different sclerite preparation methods can affect the observed sclerites. Dissecting small corals from different parts is challenging, but helps distinguish the distribution of different sclerite morphologies. However, this process may lead to the loss of some special sclerites, such as short rods with sharp projections, typically considered pharyngeal sclerites (Bayer 1956; Simpson and Watling 2011). In this study, a complete short rod with sharp sclerite projections from *H. indicodensum* sp. nov. was obtained by dissolving whole autozooids without dissection. Furthermore, this study provides electron microscopy images of the coral axis surface and describes its features. Similar descriptions have only been mentioned for *H. sulcatum* (fig. 14D in Tu et al. (2015)) and *H. bayeri* (fig. 5E in Simpson and Watling (2011)). In all cases, the axis surface was found to be not as smooth as it appears to the naked eye, with surface protrusions that may be related to the sclerite characteristics of the coenenchyme.

In conclusion, based on the results of this study, we propose the following considerations for future taxonomic work on the family Coralliidae: (1) increase the use of electron microscopy for observing coral axis surfaces and other distinctive features, ensuring that these descriptions can be applied to both complete colonies and partial branches; (2) present as many sclerite morphologies as possible and provide detailed descriptions of the predominant sclerite types; (3) conduct more comprehensive statistical analyses of Coralliidae species from different regions, including molecular phylogenetic studies, to revise the classification system of the family.

Key to the species of the genus *Hemicorallium*

This key includes 23 species from the Pacific, Atlantic and Indian Oceans. It features 21 known species recorded in WoRMS, along with the two new species described in this study (Only *Hemicorallium maderense* Johnson, 1898 is excluded due to the lack of available reference information). The key is based on the revision of the one provided by Nonaka and Hayashibara (2021).

1	Coenenchyme (except tip or autozooid mounds) colour whitish or yellowish	2
–	Coenenchyme colour orangish to reddish or white in ethanol	6
2	Autozooid mounds large and tall (>1.5 mm)	3
–	Autozooid mounds small and short (approx. 1.0 mm)	5
3	Autozooid are pale red in colour	4
–	Autozooid are whitish or yellowish in colour; double-clubs absent	*Hemicorallium jiaolongensis* sp. nov.
4	Double-clubs present	*Hemicorallium tricolor* Johnson, 1899
–	Double-clubs absent	*Hemicorallium guttatum* Tu, Dai & Jeng, 2016
5	Branching rather bushy; double-clubs present	*Hemicorallium boshuense* Kishinouye, 1903
–	Branching lateral; double-clubs absent	*Hemicorallium laauense* Bayer, 1956
6	Axis is yellowish or white in colour	7
–	Axis is light pink or pale red to dark red in colour	9
7	Autozooid mounds tall (> 1.0 mm)	8
–	Autozooid mounds short (< 1.0 mm)	*Hemicorallium niobe* Bayer, 1964
8	Double-clubs present	*Hemicorallium bayeri* Simpson & Watling, 2011
–	Double-clubs absent	*Hemicorallium meraboshi* Nonaka, Hanahara & Kakui, 2023
9	Autozooid mounds scarce, distributed biserially	10
–	Autozooid mounds crowded, predominant on one side	11
10	Autozooid mounds tall, up to 2.0 mm; small, hemispherical or irregular calyces on the cortex; double-clubs present; asymmetric multi-radiates present	*Hemicorallium abyssale* Bayer, 195
–	Autozooid mounds less than 1.5 mm in height; double-clubs present; show a considerable subdivision of the radii or are otherwise misshapen	*Hemicorallium ducale* Bayer, 1955
11	Double-clubs present	12
–	Double-clubs absent or not sure	15

12 Autozooid mounds tall (> 2.0 mm in height); axis pinkish; double-clubs abundant and surface smooth ..... *Hemicorallium indicodensum* sp. nov.
– Autozooid mounds short (< 2.0 mm in height)..... 13
13 Autozooid mounds very short (< 1.0 mm in height)..... 14
– Autozooid mounds from 1.8 to 2.0 mm in height ..... *Hemicorallium bathyrubrum* Simpson & Watling, 2011
14 Axis orange; rod sclerites up to 0.11 mm in length; double ..... *Hemicorallium taiwanicum* Tu, Dai & Jeng, 2012
– Axis pinkish to red; rod sclerites from 0.06 to 0.08 mm in length... *Hemicorallium variabile* Thomson & Henderson, 1906
15 The existence of double clubs is controversial..... 16
– Double clubs do not exist 17
16 Autozooid mounds about 2.5 mm in height (up to 3.0 mm) ..... *Hemicorallium imperiale* Bayer,1955
– Autozooid mounds about 1.25 mm in height..... *Hemicorallium sulcatum* Kishinouye, 1903
17 8-radiates abundant (> 60%)..... 18
– 8-radiates present but not abundant (< 50%) 22
18 Autozooid mounds tall (2.0–3.0 mm in height) ..... *Hemicorallium halmaheirense* Hickson, 1907
– Autozooid mounds not tall (less than1.5 mm in height)..... 19
19 Spherical sclerites absent..... *Hemicorallium muzikae* Nonaka & Hayashibara, 2021
– Spherical sclerites present 20
20 Spherical 8-radiates present..... *Hemicorallium aurantiacum* Tu, Dai & Jeng, 2016
– Spherical 8-radiates absent 21
21 Large irregular sclerites present; coenenchyme and axis orangish ..... *Hemicorallium reginae* Hickson, 1905
– Large irregular sclerites absent; coenenchyme and axis red ..... *Hemicorallium regale* Bayer, 1956
22 Most coenenchyme sclerites small (< 0.05 mm in length); coenenchyme pinkish and axis pale purple..... *Hemicorallium tokiyasui* Nonaka & Hayashibara, 2021
– Most coenenchyme sclerites small (0.05 mm in length); coenenchyme and axis red..... *Hemicorallium kaiyo* Nonaka & Hayashibara, 2021

Author contributions

XQZ designed and supervised the project. XQZ and ZXL collected the samples. HXY, ZQ, GML and LXL performed the laboratory work. HXY conducted the analyses and drafted the manuscript. ZQ, GML, LXL, XQZ, ZXL and WZL reviewed and edited the manuscript, with all authors contributing to its revision.

Data availability statement

The data of this study are available from the corresponding author upon reasonable request.

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References

Altuna Á, López-González PJ (2023) A new genus and species of deep-sea Coralliidae (Octocorallia) from the northeastern Atlantic, the first polymorphic octocoral genus with a membranous-stolonate colony growth form. Deep Sea Research Part I: Oceanographic Research Papers 201: 104157. https://doi.org/10.1016/j.dsr.2023.104157

Ardila JP, Bijker W, Tolpekin VA, Stein A (2012) Context-sensitive extraction of tree crown objects in urban areas using VHR satellite images. International journal of applied earth observation and geoinformation 15: 57–69. https://doi.org/10.1016/j.jag.2011.06.005

Bayer FM (1955) Contributions to the nomenclature, systematics, and morphology of the Octocorallia. Proceedings of the United States National Museum: https://doi.org/10.5479/si.00963801.105-3357.207

Bayer FM (1956) Descriptions and redescriptions of the Hawaiian octocorals collected by the US Fish Commission steamer" Albatross"(2. Gorgonacea: Scleraxonia). https://repository.si.edu/handle/10088/879

Bayer FM (1964) The genus *Corallium* (Gorgonacea: Scleraxonia) in the western North Atlantic Ocean. Bulletin of Marine Science 14: 465–478. https://repository.si.edu/handle/10088/884

Bayer FM, Grasshoff M, Verseveldt J (1983) Illustrated trilingual glossary of morphological and anatomical terms applied to Octocorallia. Brill Archive. https://doi.org/10.1163/9789004631915

Clewley JP (1995) Macintosh sequence analysis software: DNAStar's LaserGene. Molecular biotechnology 3: 221–224. https://doi.org/10.1007/BF02789332

De S, Gupta AK (2010) Deep-sea faunal provinces and their inferred environments in the Indian Ocean based on distribution of recent benthic foraminifera. Palaeogeography, Palaeoclimatology, Palaeoecology 291: 429–442. https://doi.org/10.1016/j.palaeo.2010.03.012

De Carvalho RG (2018) Precious corals. InColor A publication of the International Colored Gemstone Association 37: 70–78. https://doi.org/10.1038/s41598-020-64582-4

Figueroa DF, Baco AR (2014) Complete mitochondrial genomes elucidate phylogenetic relationships of the deep-sea octocoral families Coralliidae and Paragorgiidae. Deep Sea Research Part II: Topical Studies in Oceanography 99: 83–91. https://doi.org/10.1016/j.dsr2.2013.06.001

France SC, Rosel PE, Ewann J (1996) DNA sequence variation of mitochondrial large-subunit rRNA. Molecular Marine Biology and Biotechnology 5: 15–28. https://pubmed.ncbi.nlm.nih.gov/8869515/

Genin A, Dayton PK, Lonsdale PF, Spiess FN (1986) Corals on seamount peaks provide evidence of current acceleration over deep-sea topography. Nature 322: 59–61. https://doi.org/10.1038/322059a0

Gordon JD (2023) Population and Seascape Genomics of the Deep-sea Octocoral Acanella arbuscula. University of Essex. https://repository.essex.ac.uk/36055/

Hickson SJ, Versluys J (1907) Die Alcyoniden der Siboga-expedition: I. Coralliidae. Vol. 9, Buchhandlung und dr. vormals EJ Brill. https://doi.org/10.5962/bhl.title.11310

Iyer SD, Ray D (2003) Structure, tectonic and petrology of mid-oceanic ridges and the Indian scenario. Current Science: 277–289. https://api.semanticscholar.org/CorpusID:55209740

Johnson JY (1899) Notes on the Coralliida of Madeira, with Descriptions of two new Species. In: Proceedings of the Zoological Society of London 67(1): 57–64. https://doi.org/10.1111/j.1469-7998.1899.tb06845.x

Kalyaanamoorthy S, Minh BQ, Wong TK, Von Haeseler A, Jermiin LS (2017) ModelFinder: fast model selection for accurate phylogenetic estimates. Nature methods 14: 587–589. https://doi.org/10.1038/nmeth.4285

Koninklijke Akademie van W (1905) Proceedings of the section of sciences. Vol. v.8:pt.1(1905),Johannes Müller, Amsterdam. https://www.biodiversitylibrary.org/page/13877973

Kumar S, Stecher G, Tamura K (2016) MEGA7: molecular evolutionary genetics analysis version 7.0 for bigger datasets. Molecular Biology and Evolution 33: 1870–1874. https://doi.org/10.1093/molbev/msw054

Lamouroux J (1812) Extrait d'un mémoire sur la classification des Polypiers coralligènes non entièrement pierreux. Nouveaux Bulletin des Sciences, par la Société Philomathique de Paris 3: 181. https://www.biodiversitylibrary.org/page/31775884

Li Y, Xu K (2023) *Anthomastus nanhaiensis*, new species, and *Bathyalcyon robustum* Versluys, 1906, two mushroom soft corals (Octocorallia: Coralliidae) from Zhenbei Seamount in the South China Sea. Raffles Bulletin of Zoology 71: 669–680. https://doi.org/10.26107/RBZ-2023-0050

Li Y, Zhan Z, Xu K (2021) *Paragorgia papillata* sp. nov., a new bubblegum coral (Octocorallia: Paragorgiidae) from a seamount in the tropical Western Pacific. Journal of Oceanology and Limnology 39: 1758–1766. https://doi.org/10.1007/s00343-021-0404-7

McFadden CS, Van Ofwegen LP, Quattrini AM (2022) Revisionary systematics of Octocorallia (Cnidaria: Anthozoa) guided by phylogenomics. Bulletin of the Society of Systematic Biologists 1(3). https://doi.org/10.18061/bssb.v1i3.8735

Minh BQ, Nguyen MAT, Von Haeseler A (2013) Ultrafast approximation for phylogenetic bootstrap. Molecular Biology and Evolution 30: 1188–1195. https://doi.org/10.1093/molbev/mst024

Morgan NB, Andrews J, Baco AR (2023) Population genetic structure of the deep-sea precious red coral *Hemicorallium laauense* along the Hawaiian Ridge. Marine Biology 170: 150. https://doi.org/10.1007/s00227-023-04282-5

Nguyen L-T, Schmidt HA, Von Haeseler A, Minh BQ (2015) IQ-TREE: a fast and effective stochastic algorithm for estimating maximum-likelihood phylogenies. Molecular Biology and Evolution 32: 268–274. https://doi.org/10.1093/molbev/msu300

Nonaka M, Hayashibara T (2021) A report on Coralliidae (Cnidaria: Octocorallia) specimens collected from the Emperor Seamounts with descriptions of three new species. Species Diversity 26: 297–342. https://doi.org/10.12782/specdiv.26.297

Nonaka M, Muzik K (2007) Jewels of the deep sea: precious corals. Into the unknown, researching mysterious deep-sea animals Proceedings of an International Symposium. Okinawa Churaumi Aquarium, Okinawa, 23–24.

Nonaka M, Hanahara N, Kakui K (2023) A new species of Coralliidae (Cnidaria: Octocorallia) collected from Eastern Japan. Species Diversity 28: 231–243. https://doi.org/10.12782/specdiv.28.231

Ocaña Vicente O, Bethencourt DC, Ruiz AR, Herrera R, Pérez A, Abad LM, Hoyos OM, García M (2022) Morphotaxonomical and ecological study on circalitoral crypto-species of Paramuriceidae genera in the Northeast Atlantic and Mediterranean. Rev Acad Canar Cienc 34: 129–182.

Pham CK, Vandeperre F, Menezes G, Porteiro F, Isidro E, Morato T (2015) The importance of deep-sea vulnerable marine ecosystems for demersal fish in the Azores. Deep Sea Research Part I: Oceanographic Research Papers 96: 80–88. https://doi.org/10.1016/j.dsr.2014.11.004

Raju KK, Chaubey A, Amarnath D, Mudholkar A (2008) Morphotectonics of the Carlsberg Ridge between 62°20' and 66°20'E, northwest Indian Ocean. Marine Geology 252: 120–128. https://doi.org/10.1016/j.margeo.2008.03.016

Ramirez-Llodra E (2020) Deep-sea ecosystems: biodiversity and anthropogenic impacts. In: The law of the seabed. Brill Nijhoff, 36–60. https://doi.org/10.1163/9789004391567_004

Ramirez-Llodra E, Brandt A, Danovaro R, De Mol B, Escobar E, German CR, Levin LA, Martinez Arbizu P, Menot L, Buhl-Mortensen P (2010) Deep, diverse and definitely different: unique attributes of the world's largest ecosystem. Biogeosciences 7: 2851–2899. https://doi.org/10.5194/bg-7-2851-2010

Ridley SO, VPZS DG (1882) On the Arrangement of the Coralliidtœ, with Descriptions of new or rare Species. Proceedings of the Zoological Society of London 50(1): 221–234.

Roberts JM (2009) Cold-water corals: the biology and geology of deep-sea coral habitats. Cambridge University Press. https://doi.org/10.1017/CBO9780511581588

Ronquist F, Teslenko M, Van Der Mark P, Ayres DL, Darling A, Höhna S, Larget B, Liu L, Suchard MA, Huelsenbeck JP (2012) MrBayes 3.2: efficient Bayesian phylogenetic inference and model choice across a large model space. Systematic biology 61: 539–542. https://doi.org/10.1093/sysbio/sys029

Sampaio Í, Ocaña Ó, Tempera F, Henriques AB, Matos V, Porteiro FM (2009) New occurrences of *Corallium* spp.(Octocorallia, Coralliidae) in the central northeast Atlantic. ARQUIPÉLAGO-Life and Marine Sciences: 73–78. http://hdl.handle.net/10400.3/453

Sánchez JA (2005) Systematics of the bubblegum corals (Cnidaria: Octocorallia: Paragorgiidae) with description of new species from New Zealand and the Eastern Pacific. Zootaxa 1014: 1–72. https://doi.org/10.11646/zootaxa.1014.1.1

Sautya S, Ingole B, Ray D, Stöhr S, Samudrala K, Raju KK, Mudholkar A (2011) Megafaunal community structure of Andaman seamounts including the Back-arc Basin–a quantitative exploration from the

Indian Ocean. PLoS One 6: e16162. https://doi.org/10.1371/journal.pone.0016162

Sautya S, Ingole B, Jones DO, Ray D, Kameshraju K (2017) First quantitative exploration of benthic megafaunal assemblages on the mid-oceanic ridge system of the Carlsberg Ridge, Indian Ocean. Journal of the Marine Biological Association of the United Kingdom 97: 409–417. https://doi.org/10.1017/S0025315416000515

Simpson A, Watling L (2011) Precious corals (Coralliidae) from north-western Atlantic Seamounts. Journal of the Marine Biological Association of the United Kingdom 91: 369–382. https://doi.org/10.1017/S002531541000086X

Smith WH, Sandwell DT (1997) Global sea floor topography from satellite altimetry and ship depth soundings. Science 277: 1956–1962. https://doi.org/10.1126/science.277.5334.1956

Stein CA, Cochran JR (1985) The transition between the Sheba Ridge and Owen Basin: rifting of old oceanic lithosphere. Geophysical Journal International 81: 47–74. https://doi.org/10.1111/j.1365-246X.1985.tb01350.x

Takata K, Iwase F, Iguchi A, Yuasa H, Taninaka H, Iwasaki N, Uda K, Suzuki T, Nonaka M, Kikuchi T (2021) Genome-wide SNP data revealed notable spatial genetic structure in the deep-sea precious coral Corallium japonicum. Frontiers in Marine Science 8: 667481. https://doi.org/10.3389/fmars.2021.667481

Thompson JD, Higgins DG, Gibson TJ (1994) CLUSTAL W: improving the sensitivity of progressive multiple sequence alignment through sequence weighting, position-specific gap penalties and weight matrix choice. Nucleic acids research 22: 4673–4680. https://doi.org/10.1093/nar/22.22.4673

Thomson JA, Henderson WD, Simpson JJ (1906) An account of the alcyonarians collected by the Royal Indian Marine Survey Ship Investigator in the Indian Ocean. order of the Trustees of the Indian Museum. https://doi.org/10.5962/bhl.title.8279

Tsounis G, Rossi S, Grigg R, Santangelo G, Bramanti L, Gili J-M (2010) The exploitation and conservation of precious corals. CRC Press, Boca Raton(USA), 161–212. https://doi.org/10.1201/EBK1439821169-c3

Tu T-H, Dai C-F, Jeng M-S (2012) Precious corals (Octocorallia: Coralliidae) from the northern West Pacific region with descriptions of two new species. Zootaxa 3395: 1–17. https://doi.org/10.11646/zootaxa.3395.1.1

Tu T-H, Dai C-F, Jeng M-S (2015) Phylogeny and systematics of deep-sea precious corals (Anthozoa: Octocorallia: Coralliidae). Molecular Phylogenetics and Evolution 84: 173–184. https://doi.org/10.1016/j.ympev.2014.09.031

Tu T-H, Dai C-F, Jeng M-S (2016) Taxonomic revision of Coralliidae with descriptions of new species from New Caledonia and the Hawaiian Archipelago. Marine Biology Research 12: 1003–1038. https://doi.org/10.1080/17451000.2016.1241411

Uda K, Komeda Y, Fujita T, Iwasaki N, Bavestrello G, Giovine M, Cattaneo-Vietti R, Suzuki T (2013) Complete mitochondrial genomes of the Japanese pink coral (*Corallium elatius*) and the Mediterranean red coral (*Corallium rubrum*): a reevaluation of the phylogeny of the family Coralliidae based on molecular data. Comparative Biochemistry and Physiology Part D: Genomics and Proteomics 8: 209–219. https://doi.org/10.1016/j.cbd.2013.05.003

Wafar M, Venkataraman K, Ingole B, Ajmal Khan S, LokaBharathi P (2011) State of knowledge of coastal and marine biodiversity of Indian Ocean countries. PLoS One 6: e14613. https://doi.org/10.1371/journal.pone.0014613

Wei Z-F, Ta K-W, Zhang N-N, Liu S-S, Meng L, Liu K-Q, Cai C-Y, Peng X-T, Shao C-W (2024) Molecular phylogenetic relationships based on mitochondrial genomes of novel deep-sea corals (Octocorallia: Alcyonacea): Insights into slow evolution and adaptation to extreme deep-sea environments. Zoological Research 45: 215. https://doi.org/10.24272/j.issn.2095-8137.2023.039

Zhou Y, Chen C, Zhang D, Wang Y, Watanabe HK, Sun J, Bissessur D, Zhang R, Han Y, Sun D (2022) Delineating biogeographic regions in Indian Ocean deep-sea vents and implications for conservation. Diversity and Distributions 28: 2858–2870. https://doi.org/10.1111/ddi.13535

Supplementary material 1

Underwater in-situ video of *Hemicorallium indicodensum* sp. nov., holotype: FIO-IND72-JLBEN22003

Authors: Xuying Hu, Qian Zhang, Meiling Ge, Xinlong Li, Zongling Wang, Xuelei Zhang, Qinzeng Xu

Data type: mpg

Explanation note: This video was captured by the Jiaolong Human-Operated Vehicle (HOV) at a depth of 1697 m in the Carlsberg Ridge in 2022.

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Link: https://doi.org/10.3897/zse.101.139350.suppl1

Supplementary material 2

Underwater in-situ video of *Hemicorallium indicodensum* sp. nov., paratype: NDSC-IND72-JLBEN22001

Authors: Xuying Hu, Qian Zhang, Meiling Ge, Xinlong Li, Zongling Wang, Xuelei Zhang, Qinzeng Xu

Data type: mpg

Explanation note: This video was captured by the Jiaolong Human-Operated Vehicle (HOV) at a depth of 1697 m in the Carlsberg Ridge in 2022.

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Link: https://doi.org/10.3897/zse.101.139350.suppl2

Supplementary material 3

Underwater in-situ video of a suspected *Hemicorallium indicodensum* sp. nov. specimen (not been collected)

Authors: Xuying Hu, Qian Zhang, Meiling Ge, Xinlong Li, Zongling Wang, Xuelei Zhang, Qinzeng Xu

Data type: mpg

Explanation note: This video was captured by the Jiaolong Human-Operated Vehicle (HOV) at a depth of 1697 m in the Carlsberg Ridge in 2022.

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Link: https://doi.org/10.3897/zse.101.139350.suppl3

Supplementary material 4

Underwater in-situ video footage of *Hemicorallium jiaolongensis* sp. nov.

Authors: Xuying Hu, Qian Zhang, Meiling Ge, Xinlong Li, Zongling Wang, Xuelei Zhang, Qinzeng Xu

Data type: mpg

Explanation note: This video was captured by the Jiaolong Human-Operated Vehicle (HOV) at a depth of 1697 m in the Carlsberg Ridge in 2022.

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Link: https://doi.org/10.3897/zse.101.139350.suppl4

Supplementary material 5

Underwater in-situ video of a suspected *Hemicorallium jiaolongensis* sp. nov. specimen

Authors: Xuying Hu, Qian Zhang, Meiling Ge, Xinlong Li, Zongling Wang, Xuelei Zhang, Qinzeng Xu

Data type: mpg

Explanation note: This video was captured by the Jiaolong Human-Operated Vehicle (HOV) at a depth of 1697 m in the Carlsberg Ridge in 2022.

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Link: https://doi.org/10.3897/zse.101.139350.suppl5

Supplementary material 6

GenBank accession numbers of the four gene fragments used for molecular phylogenetic analysis for all species in this study

Authors: Xuying Hu, Qian Zhang, Meiling Ge, Xinlong Li, Zongling Wang, Xuelei Zhang, Qinzeng Xu

Data type: xlsx

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Link: https://doi.org/10.3897/zse.101.139350.suppl6

Supplementary material 7

Scanning electron microscope (SEM) image of the transverse section of the axis of *Hemicorallium indicodensum* sp. nov. NDSC-IND72-JLBEN22003

Authors: Xuying Hu, Qian Zhang, Meiling Ge, Xinlong Li, Zongling Wang, Xuelei Zhang, Qinzeng Xu

Data type: tif

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Link: https://doi.org/10.3897/zse.101.139350.suppl7

Supplementary material 8

Scanning electron microscope (SEM) image of the transverse section of the axis of *Hemicorallium indicodensum* sp. nov. NDSC-IND72-JLBEN22005

Authors: Xuying Hu, Qian Zhang, Meiling Ge, Xinlong Li, Zongling Wang, Xuelei Zhang, Qinzeng Xu

Data type: tif

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Link: https://doi.org/10.3897/zse.101.139350.suppl8

Supplementary material 9

Mesoglea tissue between the axis and the cortex (coenenchyme) found in *Hemicorallium indicodensum* sp. nov. NDSC-IND72-JLBEN22003

Authors: Xuying Hu, Qian Zhang, Meiling Ge, Xinlong Li, Zongling Wang, Xuelei Zhang, Qinzeng Xu

Data type: jpg

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